Analysis of Oceanic Precipitation Before the Satellite Era

Thomas M. Smith[1,2], Phillip A. Arkin[2], and Li Ren[2]

1. NOAA/NESDIS/STAR/CoRP
2. ESSIC/CICS-MD

The contents of this presentation are solely the opinions of the authors and do not constitute a statement of policy, decision, or position on behalf of NOAA or the U.S. Government

Analyses Using Satellite and In Situ Data

- Satellite-based analyses
  - Blending dense data from different satellites and instruments
  - Here monthly Global Precipitation Climatology Project (GPCP) data are used to form analysis statistics
    - GPCP for climate studies beginning 1979
    - Inter-satellite biases removed, analysis merges multiple satellite and in situ data

- This discussion: Historical analyses using satellite-based statistics (called reconstructions)
  - Satellite-based statistics for extended analyses of sparser data
  - Discuss how well reconstructions can resolve large-scale oceanic precipitation

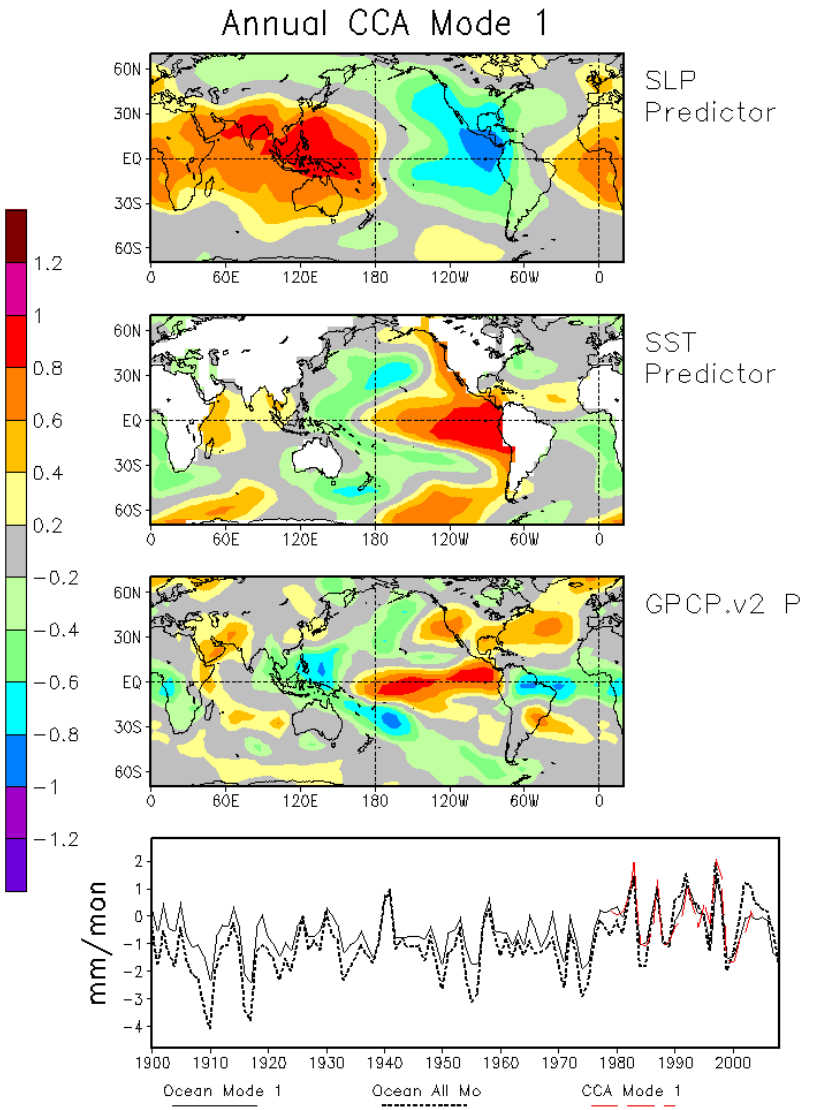
Reconstruction Method

- Spatial modes from satellite period weighted using data from historical period

- Use both Canonical Correlation Analysis (CCA) and Empirical Orthogonal Function (EOF) modes based on GPCP data
  - 1: CCA for annual anomaly first guess; use historical annual SST & SLP anomalies for annual CCA mode weights
  - 2: Annual CCA estimates over oceans and annual gauge anomaly estimates where available used to get weights for annual EOFs
  - 3: Monthly increment gauge estimates used to get weights for monthly increment EOFs
  - 4: Some versions re-inject gauge data where available

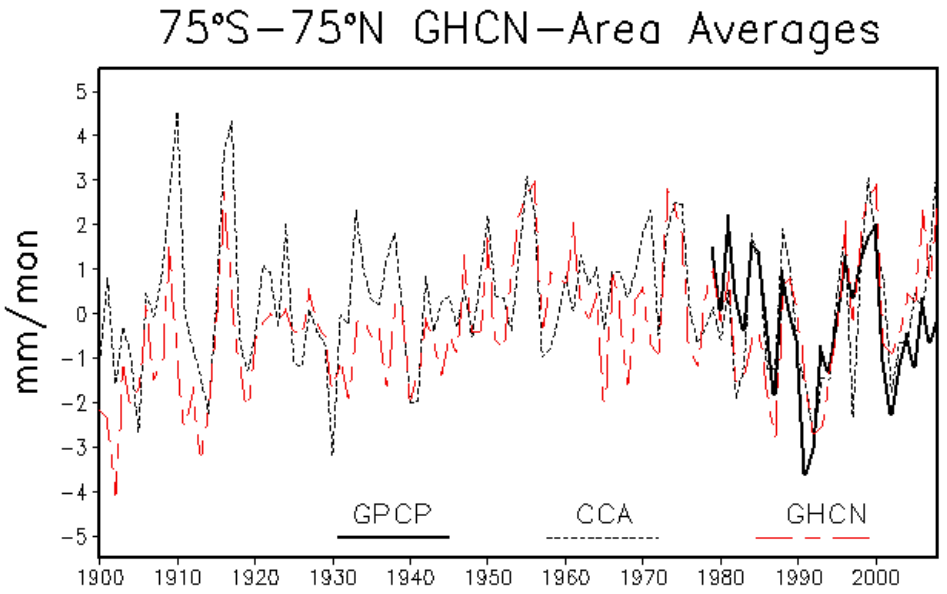
1st CCA Mode

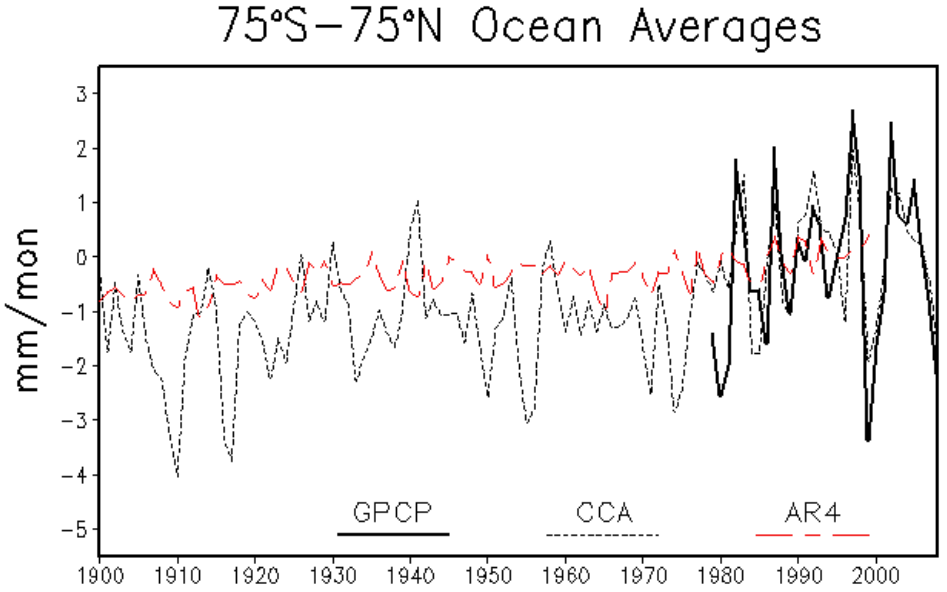
- 2 Predictors (upper panels)
- Predictand (3rd panel)
- Time series for
  - CCA mode 1 (red, 1979-2004)
  - Ocean-area recon (1900-2008)
    - Solid black (associated with mode 1)
    - Dashed black (from all 8 modes)
    - Most oceanic variations from ENSO-like 1st mode



Near-Global Annual CCA Comparisons

- Land average similar to GHCN in independent period
  - Common sampling for GHCN area
- Ocean average trend similar to AR4 ensemble
  - AR4 ensemble removes interannual variations
  - CCA trend slightly larger than AR4 trend





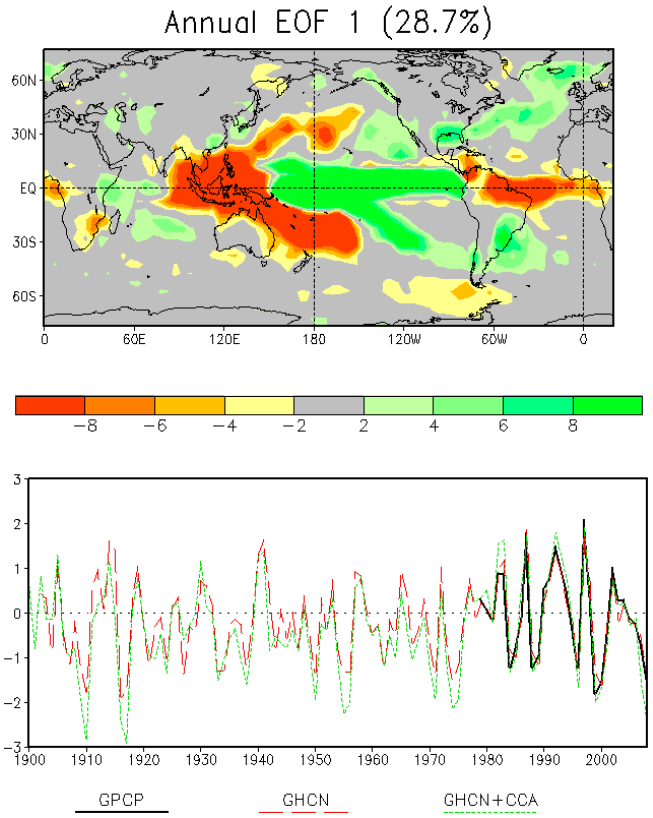
Resolution of Annual GPCP Covariance EOF Modes 1 & 2

- EOFs based on annual 1979-2008 GPCP anomalies
- Major modes resolved with historical data

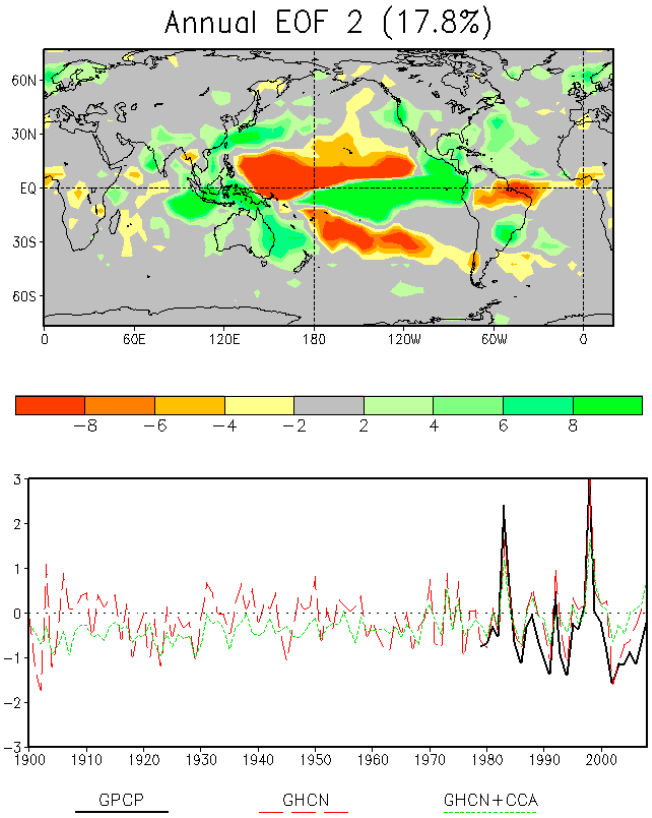
Modes 1 & 2 ENSO-like

Almost half of total GPCP variance in first 2 modes

Correlations of time series shown



Correlations:	GPCP,GHCN	GPCP,GHCN+CCA	GHCN,GHCN+CCA
1979–2008:	0.97	0.96	0.95
1900–2008:			0.73



Correlations:	GPCP,GHCN	GPCP,GHCN+CCA	GHCN,GHCN+CCA
1979–2008:	0.94	0.86	0.89
1900–2008:			0.76

cics-md
Cooperative Institute for Climate & Satellites
UNIVERSITY OF MARYLAND

Resolution of Annual GPCP Covariance EOF Modes 3 & 4

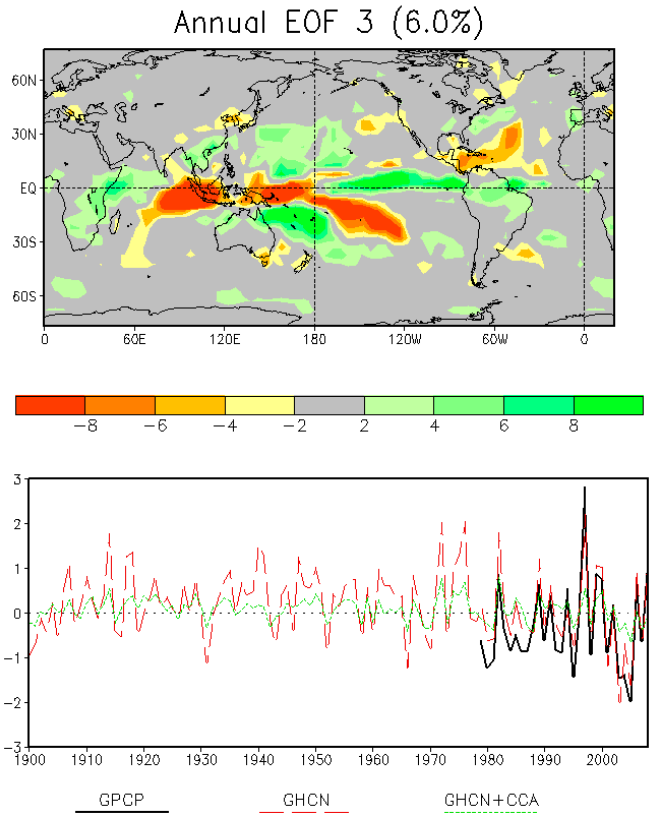
- CCA input better resolves multi-decadal at the cost of some short-period resolution

Mode 3 tropical

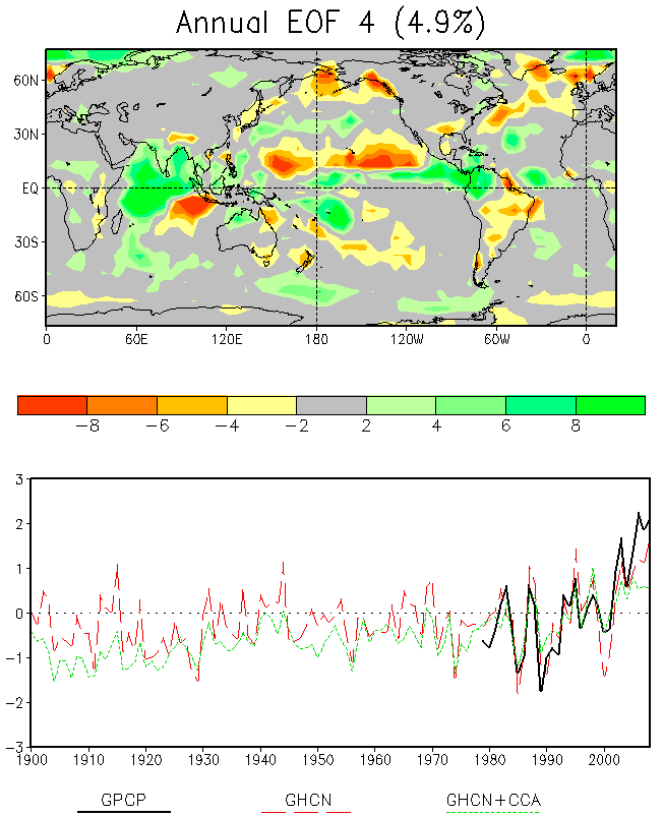
Mode 4 global multi-decadal

57.4% of total GPCP variance in first 4 modes

CCA improves oceanic multi-decadal variations



Correlations:	GPCP,GHCN	GPCP,GHCN+CCA	GHCN,GHCN+CCA
1979–2008:	0.92	0.74	0.80
1900–2008:			0.74



Correlations:	GPCP,GHCN	GPCP,GHCN+CCA	GHCN,GHCN+CCA
1979–2008:	0.86	0.84	0.85
1900–2008:			0.74

cics-md
Cooperative Institute for Climate & Satellites
UNIVERSITY OF MARYLAND

Reconstructions Errors

- Most random-data errors filtered out by fitting data to modes
- Bias errors may not be filtered out and any data adjustments needed before analysis
- Sampling error influences how well modes are represented
- Representativeness error from the reconstruction modes can be a major component
  - A limited number of modes won't resolve all base-period variance
  - Some independent-period variations may not be describable using the base-period modes

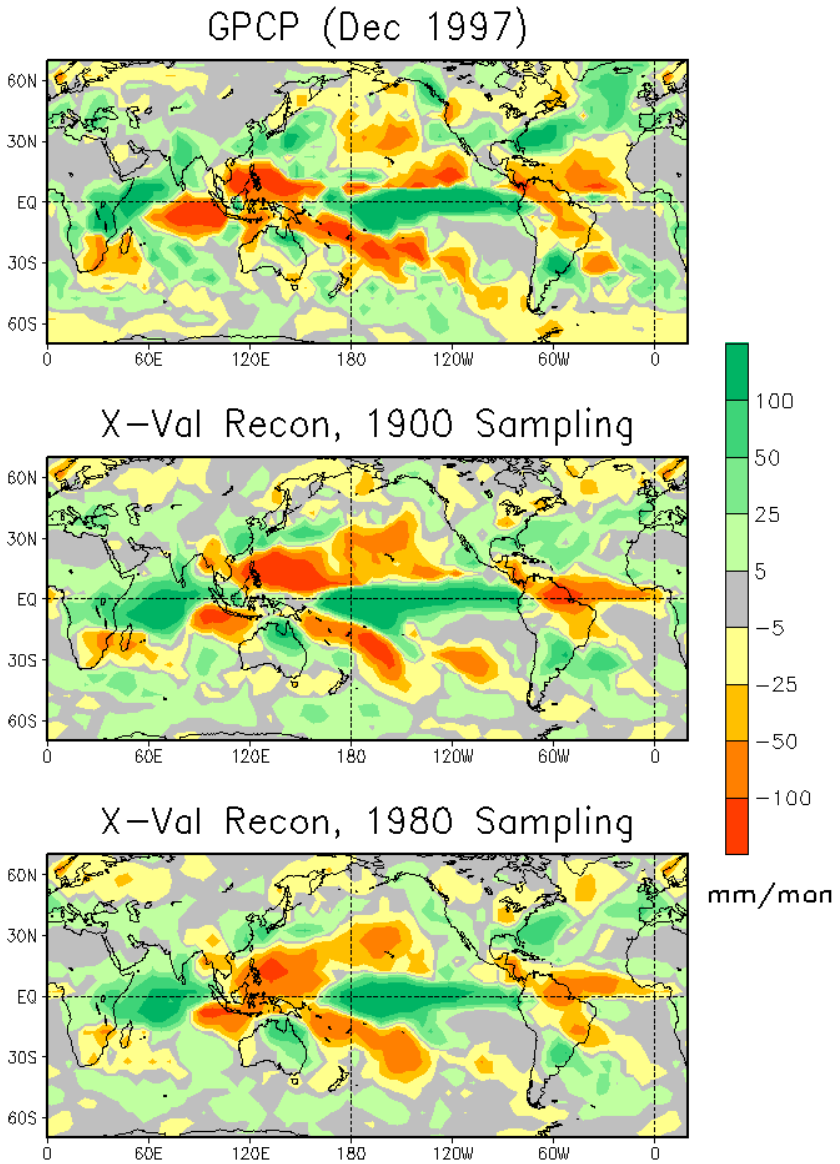
A Test of Reliability: Cross-Validation

Statistics exclude the analysis year; sampling for a historical year

Cross-validation reconstruction of GPCP; comparisons to the full analysis

Example month: Dec 1997

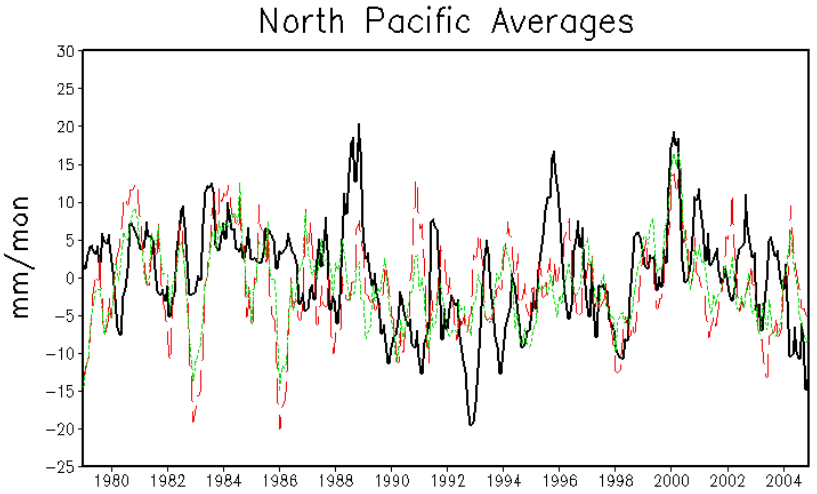
- Warm ENSO month
- Most large-scale features reconstructed, with some important differences (note Indian Ocean extent of + & - anomalies changes due to x-val modes)

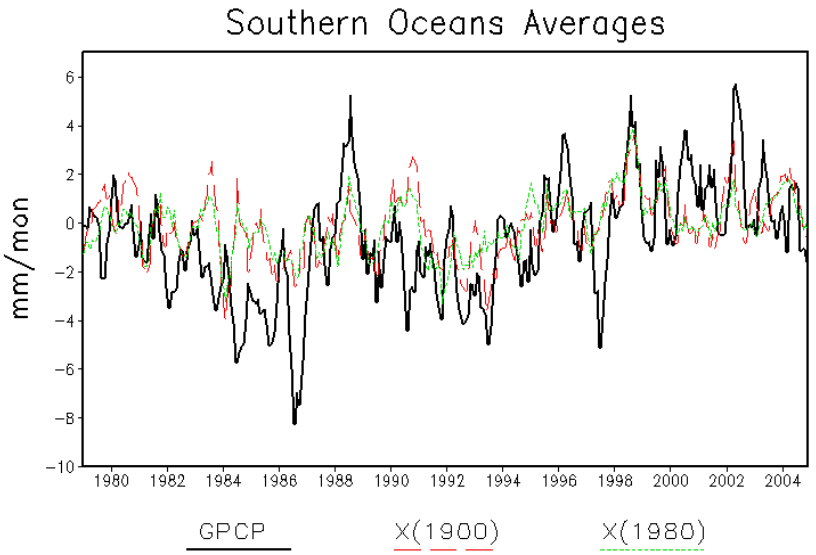


Area Averages of Cross Validation Precipitation

Two ocean areas far from gauge sampling

- North Pacific (30°N-50°N, 150°E-130°W)
- Southern Oceans (40°S-60°S, all longitudes)
- Cross-validation with 1900 and 1980 gauge sampling
- Skill in the reconstructions on interannual to multi-decadal time scales
- Individual months can have large errors
- Mode-representativeness error appears to dominate here



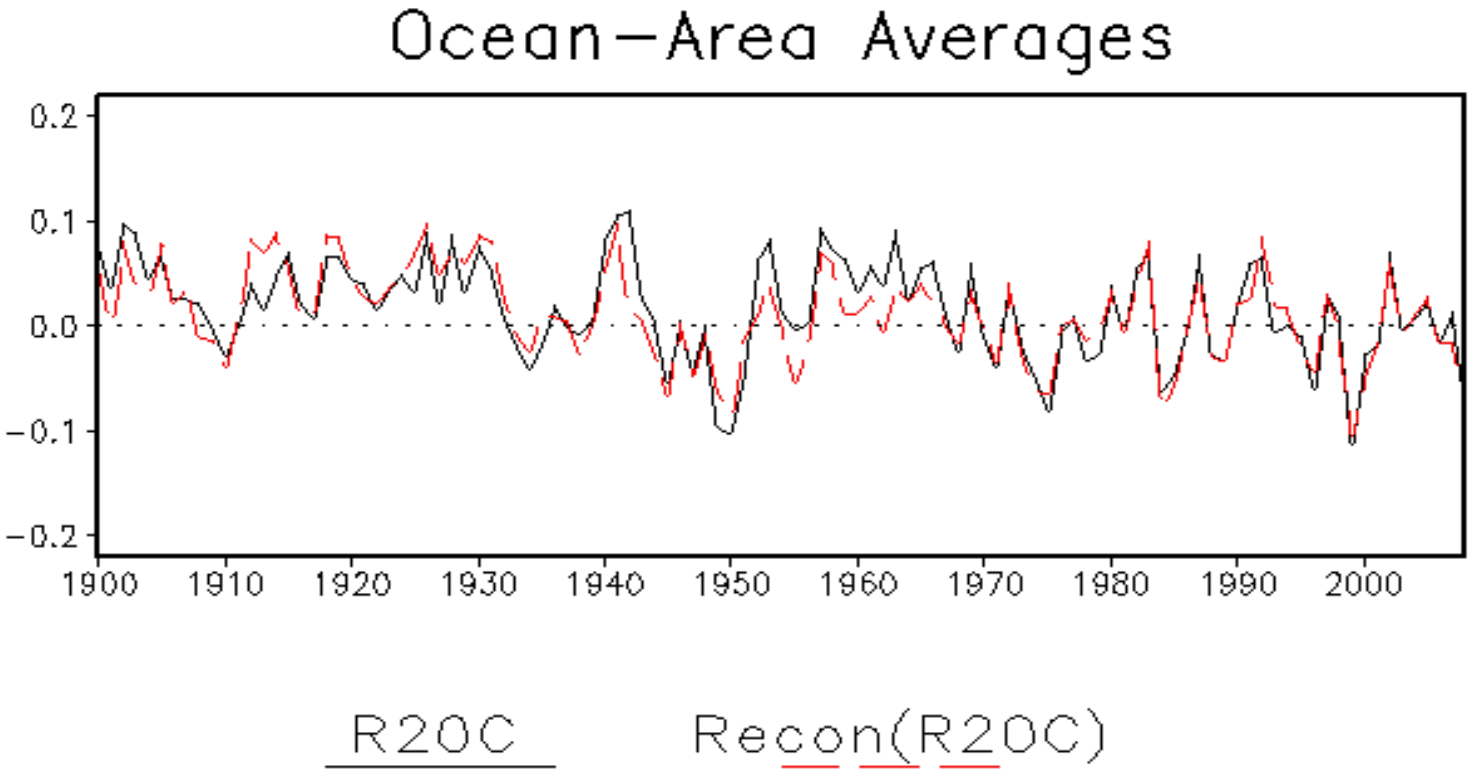


cics-md
Cooperative Institute for Climate & Satellites
UNIVERSITY OF MARYLAND

Another Test: Reconstruction of Reanalysis of the 20th Century (R20C) Precipitation

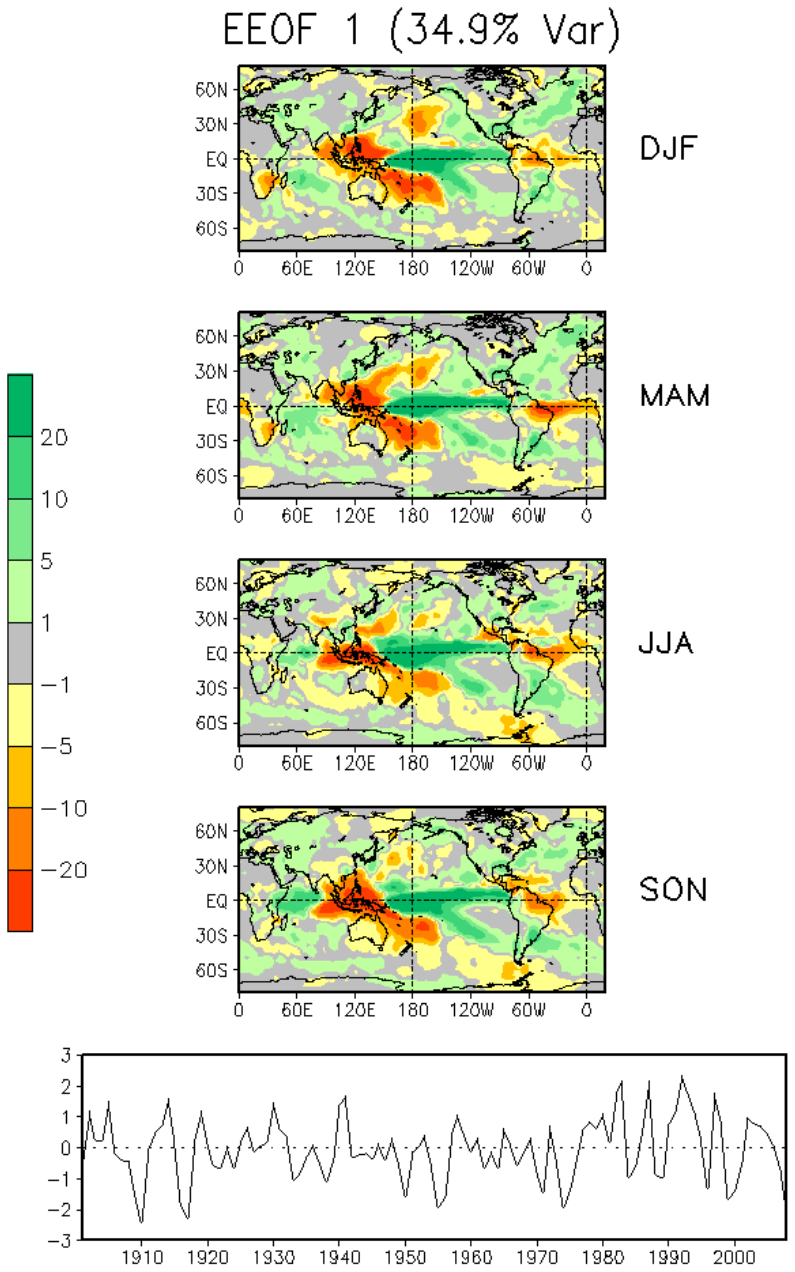
R20C: GCM using observed SST and SLP assimilation (Compo et al.)

- Spatial patterns of R20C precipitation reasonable; tropical magnitude and variations less reliable
- Reconstruction method applied to R20C & compared over oceans
- Use R20C 1979-2008 statistics, historical gauge-area sampling mask
- Reconstruction recovers pre-satellite oceanic global variations on interannual to multi-decadal time scales



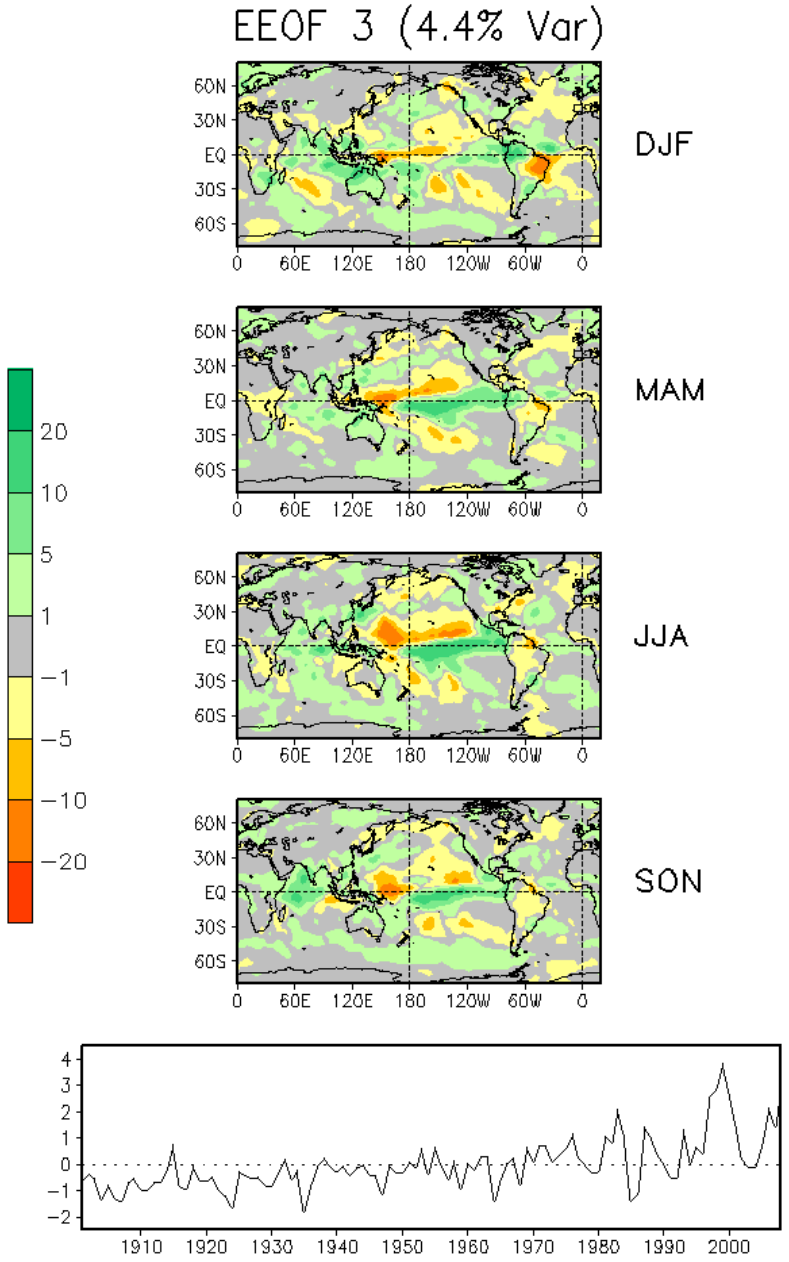
Seasonal EEOF Mode 1

- Main ENSO mode
- Tropical pattern stable, seasonal changes in extra tropics
- EEOF 2 is ENSO transition, mode 1 & 2 account for 50% of variance



Seasonal EEOF Mode 3

- Multi-decadal mode
- Seasonal variations over oceans and land
- Oceanic and land patterns apparently connected
- Much less variance accounted for than ENSO



Comparisons: Recon and CMIP5 Coupled-Model Precipitation

Multiple coupled-model runs with aerosol and GHG forcing

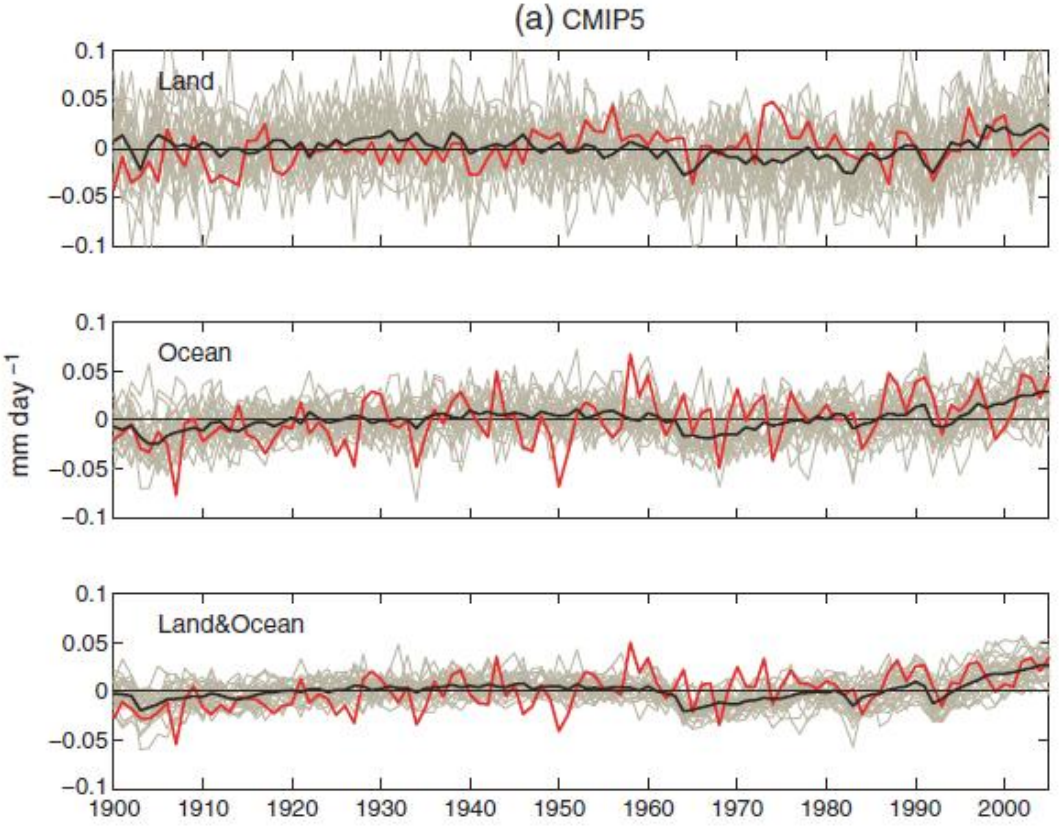
- Models indicate increasing P with increasing temperature
- Reconstruction consistent with mean model result

Grey thin lines: individual model

Black thick line: **mean of models**

Red thick line: **Recon P**

Reconstruction useful for validating climate-model runs



From Ren *et al.* (2013, JGR, **118**, 1-11)

Summary

- Interannual large-scale oceanic precipitation variations can be resolved for the pre-satellite period using satellite-based statistics and historical data
- Small scale variations on sub-seasonal time scales are much less reliable
- Reconstructions may be useful for historical climate studies, climate monitoring and for validating climate models